4.4.1 Diurnal effects

The CCIR methods assume that the maximum sky-wave field strength occurs about six hours after sunset, or approximately local midnight at the midpoint(s) of the path. However, many of the measurements were not made at local midnight at the midpoint of the path, and in this case, the data were adjusted to local midnight using the hourly correction factor derived from the European measurements. To assume that this correction is valid everywhere in the world, implies that the absorption properties of the D and E regions of the ionosphere are the same everywhere.

4.4.2 Latitudinal effects

When comparing measurements made in the U.S. with those made in Europe at similar geographical latitudes, it appears that the differences in the measured field strengths are related to the earth's magnetic field. The EBU determined that for Europe there was a significant relationship between measured field strengths and magnetic inclination, but these prediction methods use geomagnetic (dipole) latitude in their empirical relationships. As the dipole latitude is an approximation of the magnetic latitude, the use of the true magnetic latitude might reduce some of the discrepancies between observations and predictions.

4.4.3 Direction of propagation and intermediate ground-reflection loss effects

None of the MF field strength prediction methods currently in use internationally take into account the possibility of nonreciprocal propagation or the intermediate ground reflection losses on multi-hop paths. Crombie (1979) has shown that, at high solar activity, the transmission loss for MF sky-wave paths in the U.S. is greater for transmissions in the east-to-west direction than for the west-to-east direction at these latitudes. The difference, which is statistically significant, is about 9 dB for frequencies between 640 and 1530 kHz. In addition to the possibility of nonreciprocal propagation, the effect of intermediate ground-reflection losses on multi-hop paths should be examined.

4.5 Comparison of Available Methods for Predicting MF Field Strengths in Region 2 (North and South America)

The previous comparisons considered primarily MF prediction methods that are considered to be valid worldwide. Because of the requirement for a reliable MF prediction model for the Regional Administrative MF Broadcasting Conference (Region 2), a separate analysis has been made of the available MF field strength prediction methods applicable to Region 2. These methods include, in addition to the four previously discussed, the Brasilia method recently recommended by the Inter-American Conference on Telecommunications for Region 2 and a separate MF prediction method developed by CCIR IWP 6/4 and issued December 1979. The Brasilia Curve is an extension of the FCC 1935 median (50%) curve, shown in Figure 3, to distances of 13,000 km by drawing a line parallel to the Cairo North-South Curve and joining the FCC Curve at 4300 km. The IWP 6/4 method differs from the CCIR 1978 method in several respects. One of the more significant differences is the elimination of any solar cycle effect. The equation for the basic loss factor, k, in the CCIR 1978 method has been replaced by the one contained in the Wang 1979 method with the added constraint that k should not be less than 3. The use of the Wang 1979 equation for k and the elimination of solar activity greatly simplifies the calculation of the predicted MF field strengths. The final version of the IWP 6/4 method for Region 2 is presented in Appendix C.

For this comparison, the measured field strengths for 23 MF propagation paths in North America and two propagation paths between the United States and Central America were combined with the measurements for the previous paths, 23, 24, 25, 26, and 29, to form a data base for assessing the validity of these six methods for Region 2. The relevant path information for the additional Region 2 paths is given in Table 5. (Most of these measurements were used to develop the FCC 1944 curves shown in Figure 4.) The comparisons between the measured field strengths for these paths and the predicted field strengths from the Cairo, Brasilia, CCIR 1974 and 1978, Wang 1979, and IWP 6/4 methods are given in Table 6. (When either the measurements or predictions are in terms of a reference time of two hours after sunset, 2.5 dB are added to the field strengths to approximate the field strengths at midnight.)

From the rms errors between observations and predictions, the IWP 6/4 method for Region 2 can be considered the best method for predicting MF field strengths, at least for this group of paths. There is very little difference between the two CCIR and the Wang 1979 methods except for paths >2200 km. The Cairo method results are not as good as in the previous comparison except for the very long paths. The rms error for the Brasilia method is 1 dB less than the rms error for the Cairo method, and although the predicted MF field strengths are less than the Cairo Curve predictions for paths >1500 km, they are also somewhat larger than the field strengths predicted from the other methods for the U.S. paths. The rms errors for the CCIR and Wang 1979 methods

Table 5. List of FCC Propagation Paths in North and Central America

Path Number	Transmitter	Receiver	Geographic Transmitter		Coordinates Receiver		Frequency	Great Circle Distance (km)
US 1	New York City, N.Y	Baltimore, Maryland	40.9°N	73.8°W	39.3°N	76.6°W	880	300
US 2	Des Moines, Iowa	Grand Island, Nebraska	41.6°N	93.4°w	40.9°N	98.4°W	1040	425
US 3	Rochester, New York	Baltimore, Maryland	43.1°N	77.7°W	39.3°N	76.6°W	1180	430
US 4	Raleigh, North Carolina	Baltimore, Maryland	35.8°N	78.8°W	39.3°N	76.6°W	680	432
US 5	Denver, Colorado	Grand Island, Nebraska	39.5°N	104.8°W	40.9°N	98.4°W	850	568
US 6	Cincinnati, Ohio	Atlanta, Georgia	39.1°N	84.6°W	33.8°N	84.4°W	1530	592
US 7	Cincinnati, Ohio	Atlanta, Georgia	39.4°N	84.3°W	33.8°N	84.4°W	700	623
US 8	Minneapolis, Minnesota	Grand Island, Nebraska	45.2°N	93.4°W	40.9°N	98.4°W	830	623
US 9	St. Paul, Minnesota	Grand Island, Nebraska	45.0°N	93.1°W	40.9°N	98.4°W	1500	627
US 10	Cincinnati, Ohio	Baltimore, Maryland	39.4°N	84.3°W	39.3°N	76.6°W	700	662
US 11	Cincinnati, Ohio	Baltimore, Maryland	39.1°N	84.6°W	39.3°N	76.6°W	1530	687
US 12	Dallas Texas	Grand Island, Nebraska	32.9°N	97.0°W	40.9°N	98.4°W	820	898
US 13	Salt Lake City, Utah	Grand Island, Nebraska	40.8°N	112.1°W	40.9°N	98.4°W	1160	1155
US 14	Cincinnati, Ohio	Grand Island, Nebraska	39.4°N	84.3°W	40.9°N	98.4°W	700	1203
US 15	San Antonio, Texas	Grand Island, Nebraska	29.6°N	98.3°W	40.9°N	98.4°W	1200	1262
US 16	Watrous, Canada	Portland, Oregon	51.7°N	105.4°W	45.5°N	112.7°W	540	1434
US 17	Guatemala City, Guatemala	Kingsville, Texas	14.5°N	90.5°W	27.5°N	97.9°W	1020	1636
US 18	Belize, Br. Honduras	Powder Springs, Georgia	17.6°N	88.2°W	33.9°N	84.7°W	834	1850
US 19	Los Angeles, California	Grand Island, Nebraska	33.9°N	118.0°W	40.9°N	98.4°W	640	1900
US 20	Dallas, Texas	Baltimore, Maryland	32.9°N	97.0°W	39.3°N	76.6°W	820	1959
US 21	Minneapolis, Minnesota	Portland, Oregon	45.2°N	93.4°W	45.5°N	122.7°W	830	2278
US 22	St. Paul, Minnesota	Portland, Oregon	45.0°N	93.1°W	45.5°N	122.7°W	1500	2305
US 23	Dallas, Texas	Portland, Oregon	32.9°N	97.0°W	45.5°N	122.7°W	820	2598
US 24	Chicago, Illinois	Portland, Oregon	41.6°N	87.8°W	45.5°N	122.7°W	890	2818
US 25	Cincinnati, Ohio	Portland, Oregon	39.4°N	84.3°W	45.5°N	122.7°W	700	3188
US 26	New Orleans, Louisiana	Portland, Oregon	30.0°N	90.2°W	45.5°N	122.7°W	870	3297
US 27	Atlanta, Georgia	Portland, Oregon	33.8°N	84.2°W	45.5°N	122.7°W	750	3494

Table 6. Comparison of Measured Field Strengths with Predicted Field Strengths (F_o in dB relative to 1 μV/m) for Paths in North and South America

Path Number	Measured Field Strength dBμ(1 kw)	Cairo	Brazilia	CCIR '74	CCIR '78	WANG 79	IWP 6/4
US 1	44.8	46.6	46.6	53.1	52.8	52.6	52.9
US 2	44.8	46.8	46.8	48.8	48.6	48.4	48.7
US 3	44.7	46.8	46.8	48.3	48.0	48.0	48.3
US 4	44.7	46.8	46.8	49.3	49.2	48.8	49.0
US 5	46.5	46.7	46.7	45.6	45.4	45.1	45.3
US 6	47.9	46.6	46.6	44.8	44.7	45.1	45.2
US 7	44.2	46.4	46.4	45.0	44.8	44.4	44.5
US 8	38.0	46.4	46.4	43.5	43.3	42.6	42.9
US 9	41.2	46.4	46.4	42.4	42.2	42.6	42.9
US 10	41.5	46.2	46.2	43.5	43.3	42.6	42.9
US 11	44.9	46.2	46.2	41.9	41.7	42.1	42.4
US 12	43.9	43.9	43.9	39.8	39.7	39.3	39.5
US 13	40.3	37.5	37.5	33.9	33.8	33.8	34.0
US 14	30.6	37.2	37.2	34.0	33.8	32.5	32.8
US 15	39.7	36.6	36.6	34.1	34.1	34.4	34.5
US 16	25.6	33.9	33.9	28.3	27.9	24.3	24.7
US 17	37.5	30.6	30.3	32.9	33.2	34.7	34.4
US 18	35.0	29.1	27.8	30.4	30.6	31.4	31.2
US 19	23.6	28.1	27.4	27.2	27.2	25.9	26.0
US 20	24.2	27.7	26.5	25.4	25.4	24.6	24.7
US 21	10.4	25.2	23.0	16.2	16.0	13.7	13.9
US 22	10.9	25.0	22.6	12.0	11.8	13.4	13.6
US 23	13.9	23.3	20.0	18.0	18.1	16.9	17.0
US 24	0.1	21.4	17.4	10.6	10.6	8.5	8.8
US 25	0.1	19.1	14.8	9.0	9.0	5.4	5.6
US 26	13.3	18.3	13.9	11.3	11.5	10.5	10.6
US 27	-1.9	17.2	13.0	8.3	8.4	5.9	6.1
# 23	2.0	3.2	-3.7	-6.6	-5.7	9.3	-1.9
# 24	2.0	3.0	3.9	0.3	1.7	15.6	4.6
# 25	-2.0	2.8	3.3	-0.9	0.6	15.0	4.1
# 26	2.0	2.5	-4.4	-8.1	-7.2	7.9	-3.8
# 29	2.0	1.7	-4.5	-12.8	-11.9	3.5	-9.0
RMS Error		8.2	7.1	5.8	5.7	5.7	4.7

indicate that there are no significant differences between the field strength predictions using these methods except for the longer paths.

From Table 6, it can be observed that for paths <2000 km, the differences between the predicted MF field strengths for the different prediction methods is insignificant; the rms error is approximately 4.0 dB for all methods. However, for the U.S. paths >2000 km (21 through 27), there is more variability in the predicted MF field strengths. Beyond 2200 km, propagation of the radio wave would involve two ionospheric reflections. The rms error for these seven paths is 15.6 dB for Cairo, 12.4 dB for Brasilia, 7.1 dB for CCIR 1974 and 1978, 5.3 dB for Wang 1979, and 5.4 dB for the IWP 6/4 predictions. From these results, it appears that either the Wang 1979 or the IWP 6/4 predictions are more reasonable for MF paths between 2200 and 3500 km in Region 2.

However, for paths >8000 km (23, 24, 25, 26, and 29), there is less variability between the predictions than for the U.S. paths 21 through 27. The rms error for the predictions for these five paths is 2.3 dB for Cairo, 5.4 dB for Brasilia, 8.9 dB for CCIR 1974, 8.3 dB for CCIR 1978, 10.6 dB for Wang, and 6.5 dB for IWP 6/4. (The Wang 1979 method would give approximately the same results as the IWP 6/4 method if the loss factor, k, is limited to 3 in the calculation of the field strengths for these paths.) The Cairo North-South Curve predictions appear to be the preferred method for very long paths in Region 2.

5. RELIABILITY OF MF FIELD STRENGTH MEASUREMENTS

When comparing measurements with predictions, lack of information about the reliability of the data makes it difficult to realistically assess the accuracy and/or suitability of any prediction method. There are a number of uncertainties concerning the controls and conditions under which many of these observations were made. For example, the measurements used for the Cairo Curves were normalized to 1 kW radiated, but the transmitting antennas were one-half wavelength long. Should an additional correction factor be applied to the measurements before comparing them with predictions that have assumed a short vertical antenna? As the CCIR and Wang prediction methods only approximate the correction to account for the transmitting antenna gains, this could also explain some of the discrepancies between the measurements and predictions. Some of the measurement campaigns extended over several years, and in some areas these measurements indicate a seasonal variation. The Cairo measurements were made only in local winter and summer; if there is a seasonal